

TOTAL SOLAR ECLIPSE

**ANSWERS
TO
ALL YOUR
QUESTIONS**

TOTAL SOLAR ECLIPS

**ANSWERS
TO
ALL YOUR
QUESTIONS**

**Narender K. .Sehgal
Sandip Bhattacharya**



VIGYAN PRASAR

Published by
Vigyan Prasara
C-24, Qutab Institutional Area
New Delhi - 110 016
(Regd. office: Technology Bhawan, New Delhi - 110 016)
Phones: 6967532, 6864157
Fax: 6965986, 6965980
E-mail: vigyan@hub.nic.in
vigyanp@iasdl01.vsnl.net.in
Internet: <http://www.vigyanprasar.com>

Total Solar Eclipse: Answers to All Your Questions

Authors:
Narender K. Sehgal
Sandip Bhattacharya
Copyright © 1995 by Vigyan Prasara
First Edition: 1995
Second Edition: 1999
ISBN: 81-7480-053-0
Layout and Design at Vigyan Prasara
Illustrations: Chaitali Chatterjee

All right reserved. No part of this book may be reproduced or utilized in any form or by means, electronic or mechanical, including photocopying, recording, or by any information storage and retrieval system, without permission in writing from the publisher.

Printed in India

PREFACE

Solar eclipses, particularly total solar eclipses, are breath-taking natural phenomena. Eclipses are rare events and a total solar eclipse is even rarer. Eclipses are well-understood scientifically. There is no reason how to miss viewing such a spectacular event as a total solar eclipse(TSE). In fact, such an opportunity comes only in a lifetime. In the recent past India has witnessed two TSEs, in 1980, it was in parts of southern India that the TSE was visible. In 1995 the path of totality passed over well-populated areas of Rajasthan, UP, Bihar and WB. Keeping in view the experience of TSE-1980 when hardly any people (other than the scientists and a few enthusiasts) ventured out of their houses, Vigyan Prasar in collaboration with NCSTC (DST) had launched a nation-wide one year long campaign to dispel myths and spread awareness about scientific aspects of eclipses. This booklet was brought out as part of this campaign. The forthcoming TSE on 11 August 1999 will be the last of this century to be visible from Indian soil. It is therefore desirable that this time too many Indians—children of all ages—make an effort to come out and watch the eclipse safely and confidently. To help people make up their minds and to prepare them for the big event, we have put together, in the accompanying pages, a whole set of questions on various aspects of eclipses—scientific, social, prevalent beliefs and practices and so on—together with answers based on their scientific understanding. Such

questions are likely to arise in common peoples' minds. They include those which have to do with prevalent misconceptions, fears and so on. Besides a list of DOs and DON'Ts for safe viewing of the eclipse relevant maps, charts and tables have been reproduced from the publication, *Total Solar Eclipse of 11 August 1999 , circumstances relating to India* issued by the India Meteorological Department.

It is hoped that after going through the answers provided, many readers would be enthused and encouraged to watch the eclipse safely and without any fear of damage to eyesight, or other ill-effects.

Narender K. Sehgal

Q.1 What is an eclipse?

Ans. Eclipse is a simple phenomenon. Let's say an object is receiving light from a source situated at some distance. If a body crosses the path of this light, it will cast a shadow on the lighted object. Also, viewed from where the object is, the light source would be eclipsed fully or partly depending on the size of the body and its distance from the

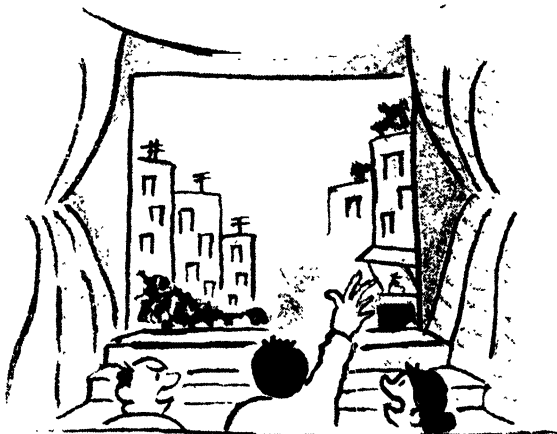


Fig. 1

object. One comes across several examples of this in our everyday life. In a cinema hall, during a movie, we have often seen a shadow on the screen whenever someone comes in the way of or moves across the light beam from the projection room at the back of the cinema hall.

Q.2 How do eclipses take place?

Ans. Eclipses take place when, during the course of their normal movements in their respective orbits

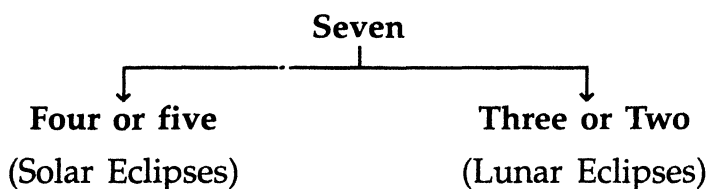
(of the moon around the earth and of the earth around the Sun) one of them --the moon or the earth--happens to block out partly or completely the Sun's light from reaching the other. When the moon comes in between the Sun and the earth, a solar eclipse takes place and a lunar eclips can be seen when the Sun and the moon happen to line up with the earth in between.

Q.3 Why does a solar or a lunar eclipse take place?

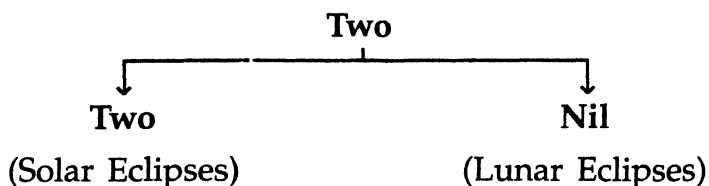
Ans. Because the earth and the moon are non-luminous bodies and they cast their shadows in space in the light of the Sun. And some times the shadow of either one of them falls upon the other, making the Sun or the moon to appear partially or fully eclipsed.

Q.4 How often do eclipses take place?

Ans. The maximum number of eclipses in a year is



The minimum number of eclipse in a year is



Note : From a particular place on earth, a total solar eclipse is visible, on an average, only once in 360 years.

Q.5 Why can't we see all the eclipses that take place from our locations?

Ans. Most of the time the eclipses are visible only from the seas or from other inaccessible and uninhabited regions of the earth like mountains, deserts and forests. This is not at all surprising since two-thirds of the earth's surface is covered with rivers, seas and oceans.

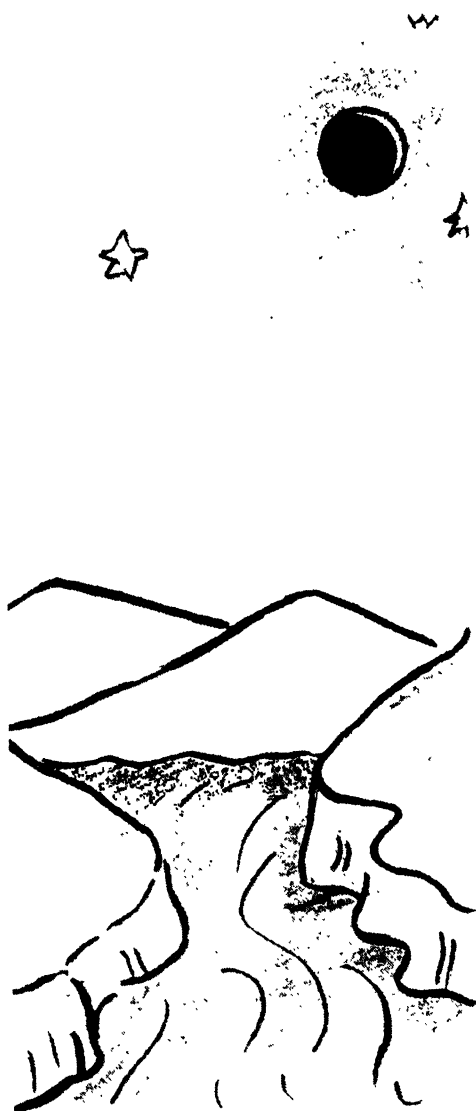


Fig. 2

Q.6 What is so special about a total solar eclipse (TSE)?

Ans. For ages the Sun has been revered as a sure, steady and constant source of energy. It is so regular in its apparent movement, in terms of its daily rising and setting in the sky that civilizations around the



Fig. 3

world have worshipped it as a god. So, any unexpected or sudden change in the apparent constancy of the Sun was regarded with awe, fear, anxiety and as a catastrophe, in the past. And, in the absence of anything better, people were willing to accept any 'explanations', prescriptions or rituals which appeared to help them cope with their fears and ward off any supposed or 'impending' ill-effects or disasters. There are several things that make a

TSE so special: (i) Only rarely is it visible from a place on earth; (ii) the sequence of events and the sight of TSE are visually awe-inspiring and spectacular; (iii) some scientific observations and experiments are possible only during a TSE; and (iv) all the myths, legends and superstitions associated with TSE would not have been there if it were not for the rarity of their occurrence, or if TSEs were taking place regularly and quite often. This could have indeed been the case if the moon's orbital plane and the earth's orbital plane had coincided.

Q.7 How are phases of the moon different from lunar eclipses?

Ans. The moon itself is a non-luminous body. It shines only by reflecting the light of the Sun. Moreover, only that portion of the moon shines, which is visible from the earth and upon which the sunrays fall directly. As the moon orbits around the earth — in a slightly tilted plane which makes a 5 degree angle with the earth's orbital plane — the shining part of it increases and decreases in size, on account of the changing geometry between the earth, the Sun and the moon. These are known as phases of the moon: from full moon to new moon during a month.

On the other hand, a lunar eclipse takes place, as mentioned earlier, when the moon enters into the shadow of the earth which obstructs the sunlight falling on it directly, making the moon disappear in part or in full, for the duration of the eclipse.

Q.8 When did the earliest recorded total solar eclipse take place?

Ans. The earliest known record of a total solar eclipse (TSE) goes back more than 4000 years. Shu Ching, the ancient Chronicle, has in it description of a TSE that took place on 22 October 2137 B.C. (There are references to TSEs in some ancient Indian epics, like the Mahabharata but they can't be termed as 'records' in the same sense as the Chinese record aforementioned.)

Q.9. Should or should one not view a solar eclipse?

Ans. Eclipses are rare events and a TSE is even rarer. They are breathtaking natural phenomena, well understood scientifically. One should by all means view a solar eclipse, of course with proper safety precautions, in a way that would be safe for one's eyes. (Please see answer to the following question.)



Fig. 4

Q.10. How can one safely view a solar eclipse?

Ans. The Sun can be viewed safely with unaided eyes only during the few brief moments when it is eclipsed totally during a TSE. Partial or annular solar eclipses are never safe to watch directly without taking proper safety precautions for the eyes. Even when 99% of the Sun's disc is obscured by the moon, during the partial phases, the remaining photospheric crescent is bright enough to require protection for the eyes.

DO NOT ATTEMPT TO OBSERVE THE PARTIAL OR ANNULAR PHASES OF ANY SOLAR ECLIPSE WITH THE NAKED EYE. THIS MAY CAUSE PERMANENT DAMAGE TO EYESIGHT, AND EVEN BLINDNESS.

There are several methods for safe viewing of the solar eclipse in its partial phases. Except when the Sun is totally eclipsed, it is best and safest to see it only indirectly i.e. its reflected or projected image. There are many ways of doing it:

10.1 An aluminium foil or a piece of cardboard with a pin-hole of 1 mm diameter can be used to project an image of the Sun under shade. Such a pin-hole, about a meter away from the projection surface, gives a fairly clear image of the Sun.

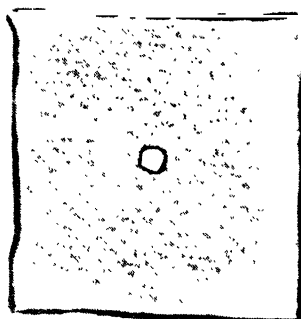


Fig. 5

10.2 A small mirror covered with a piece of paper (preferably, black paper) having a circular hole of (diameter 1-2 cm) at its centre can be used to project an image of the Sun on a shaded wall, or on a wall indoors. Smaller the diameter of

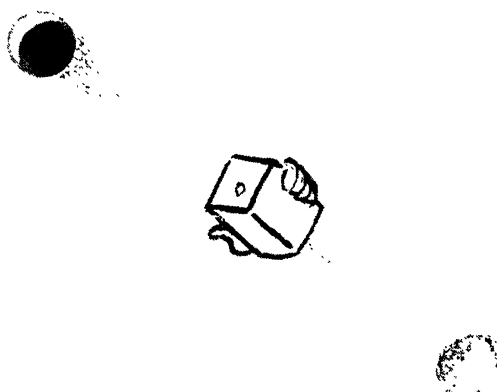


Fig. 6

the hole sharper is the image. However, the gain in sharpness is at the cost of brightness.

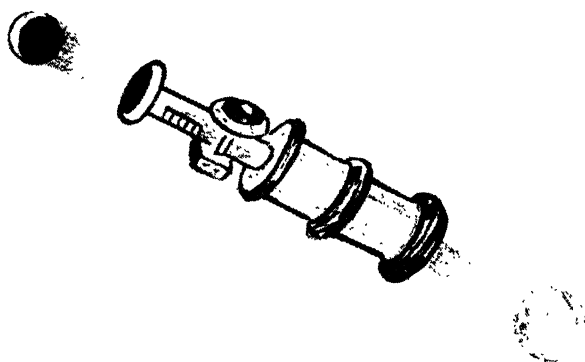


Fig. 7

- 10.3** A small telescope or binocular can also be used to back-project the magnified image of the Sun on a white screen/card/wall. But, if binoculars or the telescope has any plastic parts then it would be necessary to protect them from getting heated and melting. **In no case should these instruments be used for direct viewing of the partially eclipsed Sun.**
- 10.4** Direct viewing of the Sun can be done only by using appropriate filters, designed for the purpose. Such filters generally have aluminium, chromium or silver deposits to absorb the extra visible and infrared energy. Experienced amateur and professional astronomers sometimes use layers of completely exposed and fully developed black and white film, provided the film contains a silver emulsion.
- 10.5** One filter entirely safe for directly viewing the Sun is a shade 14 rectangular welder's glass, available through welding supply stores. It transmits only 1 part in 3,70,000 of the incident light and meets strict tolerances on transmission of invisible ultraviolet and infrared as well. However, only mylar or glass filters specifically designed for the purpose should be used with telescopes or binoculars.
- 10.6 Unsafe filters :** Colour film, non-silvered black and white film, smoked glass, photographic neutral density filters and polarising filters are not safe. Solar filters designed to thread into eye pieces and often sold with inexpensive

telescopes are also dangerous. They should not be used for viewing the Sun at any time since they often crack from overheating.

10.7 Do not experiment with any filters unless you can be reasonably certain that they are safe.

10.8 The Sun emits energy in all regions of the electromagnetic spectrum : slightly over 40% of the energy is emitted in the visible, more than 50% in the infrared, under 10% in the near ultraviolet, and the percentage is negligible in other wavelengths. Especially during eclipses, while the visible light can also deliver dangerous quantities of heat to the retinal image, damage to the eyes is caused by invisible infrared and ultraviolet wave lengths. **So, except during totality, it is best and safest to see only a reflection or projection of the Sun's image.**

TEST FOR A SAFE FILTER

According to a communication from a doctor, published in the journal *Archives of Ophthalmology* :

"Any filter should therefore be safe which reduces the intensity sufficiently so that the printed code on a standard 60-watt frosted bulb is no longer readable. ... The light of the bulb in a dark room will then appear as a glow similar to that of a full moon on a moderately bright night." (David G. Cogan, MD, 243 Charles street Boston 14, Ma, USA)

The doctor has also added : "While there is adequate theoretical and experimental evidence to indicate that filters of this density are safe for eclipse viewing, we cannot accept legal liability for these recommendations..."

Q.11. Are any 'special' rays emitted during a solar eclipse?

Ans. During an eclipse, the Sun continues to emit the same radiations as it does at other times. Only, during an eclipse, and only at places where the eclipse is visible, a part of the solar radiation coming towards the earth is blocked/absorbed by the moon while passing in front of the Sun. So, if anything, during an eclipse at places wherefrom it is visible, only a part of the solar radiation is able to reach the earth. So, not only no 'special rays' get emitted from an eclipsed Sun, the sunrays which reach the earth are as 'harmful' (if let into your naked eyes) or 'useful' as they are on normal (eclipseless) days.

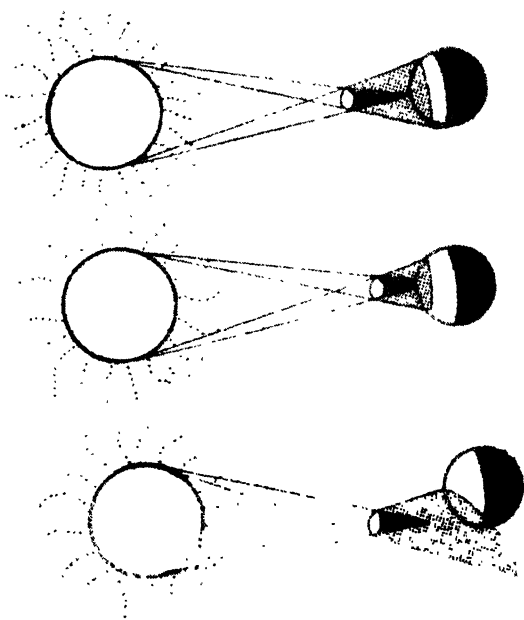


Fig. 8

Q.12 In what way and how does solar radiation damage the naked eye?

Ans. The basic process which is responsible for damage from solar radiation to eyesight is the same whether it takes place during a solar eclipse or on a normal sunny day. Studies have shown that damage to eyes caused during eclipses (i.e. eclipse blindness) is wholly thermic in nature, due to the "intense concentration of the solar energy upon the retina by the refracting system of the eye itself forming an image of destructive intensity."

When we look at the Sun directly with our naked eyes, the estimated concentration of energy in the image is approximately 113×10^6 ergs (equivalent to about 4 calories) per square cm per second. Even if only a part of this energy gets into the retinal image while looking at a partially eclipsed Sun, the concentration of energy would be sufficient to cause a destructive lesion. This lesion spreads in both directions, forward through the retina into the rods and cones, and backward into the choroid.

It has been shown that the general absorption of the media of the eye for radiant energy is closely similar to that of water in a layer of equal thickness. For radiation from low temperature sources like incandescent lamps and ordinary flames, the cornea and lens of the eye absorb the rays of ultraviolet light, the water content of the eye absorbs the greater part of the infrared radiation and only waves from the visible spectrum traverse the eye to the retina

(longer wavelengths being more than 90% absorbed). But in case of a powerful radiation source like the Sun the radiation is of such a character that it is not absorbed and hence the energy in the image may rise to great intensity.

It has been calculated that the critical period for development of eclipse blindness is, of the order of a minute or less and exposure of even a few seconds would be highly dangerous were it not for the extreme miosis (pupillary diameter 1.6 to 2 mm) set up when looking at the Sun, and the wandering of the image on the retina. Rapid shifting of the focal image on the retina gives the tissue opportunity for cooling. Results of exposure under diverse conditions would vary according to the time necessary to develop heat effects. Looking through a glass, or a filter or exposure to reflected sunlight or other sources of radiation as arc light, incandescent metals and so forth, will damage the retina only if the effective amounts of heat are generated.

Because of the retinal circulation, heat generated in the retina does not accumulate, and, therefore, repeated exposures each producing rise in temperature below the point at which injury to the tissue occurs, would have no effect even though repeated many times.

[**Note:** The above is adopted and some lines lifted almost verbatim from "Editorials" in the *American Journal of Ophthalmology*, 28 (1945) pages 1161-65.]

Q.13 Why do scientists go chasing total solar eclipses wherever they take place?

Ans. Total solar eclipses (TSEs) are rare phenomena and certain types of scientific observations can only be carried out during such occurrences. Because of the brilliance and high luminosity of the sunlight, many of the surface features and phenomena for example cannot be studied on normal days. To study

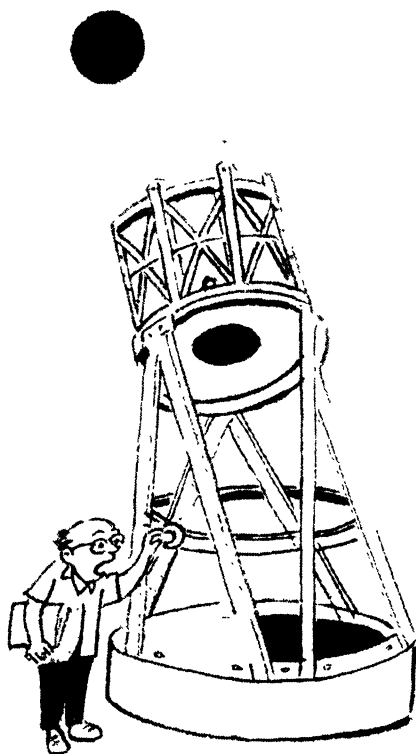


Fig. 9

these and other such phenomena, scientists go whenever TSEs are visible. Also, many important scientific discoveries have been made as a result of observations made during TSEs. Some important examples are :

1. The first photographs of the solar corona were taken during the TSE on 28 July 1851.
2. The first observation of the green coronal line was made during the TSE on 7 August 1863.
3. The discovery of the reversing layer of the Sun was made during the TSE on 28 December 1870.
4. A bright comet was discovered on the photographs of the TSE of 17 May 1882.
5. A confirmation of the Einstein's theory of General Relativity, which predicted bending of light by gravitation, was made during the TSE of 29 May 1919.
6. The spectral line of the element Helium was first seen during the Indian total solar eclipse of August 18, 1861, at Guntur in Andhra Pradesh.

Q.14 What kind of scientific experiments can be done during a total solar eclipse and why?

Ans. Several kinds of scientific experiments and observations are carried out during a total solar eclipse:

14.1 Astronomy experiments

As the moon slowly occults the disc of the Sun, several surface features of the Sun can be studied, revealing structures of sunspots and other active regions of the Sun. Variations in magnetic field, ultraviolet and X-ray emissions by the atmosphere of the Sun and the strengths of several spectral lines can be mapped. The entire atmosphere of the Sun, the chromosphere and corona can be studied with reasonable accuracy only during a total solar eclipse.

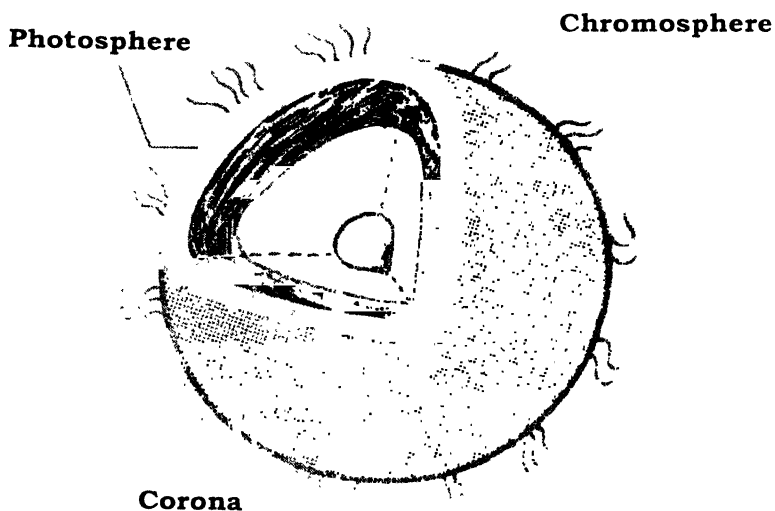


Fig. 10

14.2 Atmospheric and Ionospheric Experiments.

As the shadow of the moon sweeps over the earth, certain spontaneous changes take place

in the earth's atmosphere including the ionosphere which can be studied during a total solar eclipse.

14.3 Life Science Experiments

As the Sun slowly gets obscured by the moon, animals and birds get puzzled. They begin behaving as they would near the time of sunset



Fig. 11

on normal days. A study of animal behaviour may yield interesting results during a total solar eclipse.

Q.15 Is it safe to eat during a solar eclipse?

Ans. The prevalent practice of discarding all food of the eclipse period and of not eating any food during an eclipse has no scientifically tested basis. It is as

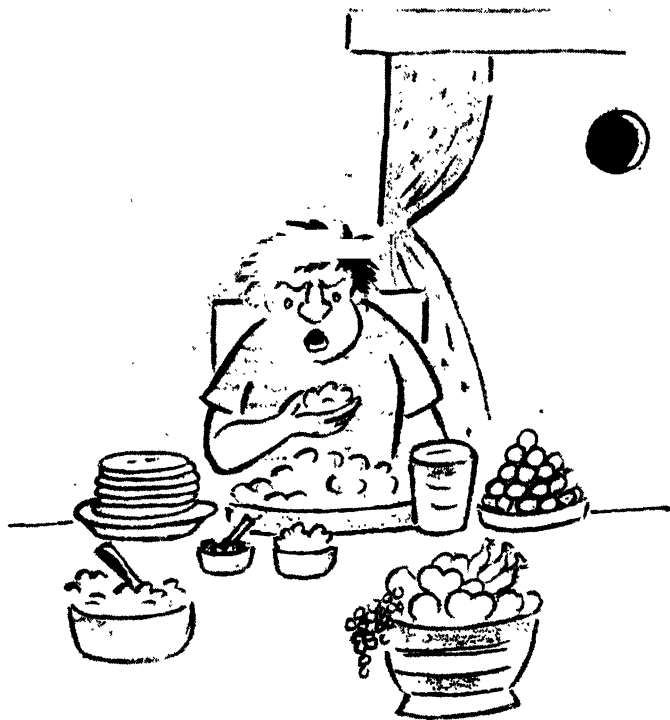


Fig. 12

safe to eat during an eclipse, as it is on a normal day, or during the night.

Q.16 Are there any ISI specifications for a solar filter which would be safe for viewing the Sun? Do such specifications exist anywhere in the world?

Ans. At present there do not exist any ISI specifications for a filter which could be employed to safely view the Sun. Our inquiries with the Indian Standards Institution (ISI) have confirmed this. Also, according to ISI, specifications for such filters have not been issued anywhere in the world. However, we have been able to get information to the effect that technical specifications for a filter to safely view the Sun were issued by the Mexican Government 4 months in advance of the total solar eclipse visible in that country on 11 July 1991.

In fact, just one American company was able to sell 35 lakh solar filters in Mexico, for the July 1991 eclipse visible from Mexico and 8 lakh such filters in the tiny nation of Bolivia (for the November 1994 TSE visible there).

Q.17 The Moon is so much smaller in size than the Sun. How then, is it able to exactly cover the solar disc during a total solar eclipse?

Ans. The moon is actually about 400 times smaller in size than the Sun. However, because it is about 400 times closer to the earth than the Sun, the apparent size of the moon as seen from the earth almost equals the apparent size of the Sun. This is

just a coincidence and responsible for the spectacular sight presented by a TSE. In fact, any round object put away about 108 times its diameter from a viewer can entirely cover the disc of the Sun, or of the full moon.

**Q.18 How long does a total solar eclipse last?
How long does a lunar eclipse last?**

Ans. Because of the existing geometry and dynamics of the earth-moon-Sun system, the maximum duration of a total solar eclipse, as can be seen from a given place on earth, is seven and a half minutes. A total lunar eclipse, on the other hand, can last for a couple of hours.

Q.19 Is an eclipse unsafe for an unborn child in a mother's womb?

Ans. For a pregnant woman and for the unborn child she is carrying, a solar eclipse should be as safe or unsafe as the Sun is for them on any normal day during daytime or when the Sun is setting. There is no scientific basis for the belief that a solar eclipse is 'harmful' for unborn children in wombs of pregnant woman.

Q.20 Is it necessary to take a bath after an eclipse?

Ans. Because of an eclipse per se, there is no 'necessity' of taking a bath — i.e. there is no scientific basis for such a 'necessity'. However, if one does want to take a bath or a shower after an eclipse, it won't do any harm.

Q.21 From my place (town) when will I be able to see a total solar eclipse again after the one in October this year?



Fig. 13

Ans. Simple statistical calculations indicate that from the same location on earth, a TSE is likely to be visible only once in 360 years. So, if you happen to be located on the path of totality (please see map elsewhere in this booklet), the next TSE visible from your place is likely to come only sometime in the 24th century.

Q.22 What is a Saros cycle?

Ans. The circumstances of an eclipse (the respective positions of the earth, the moon and the Sun) repeat with remarkable regularity in a cycle of about 18 years. This fact was discovered by the Chaldean astronomers way back in 400 B.C. and is known as the Saros Cycle. The exact period of the cycle is 6585.3 days. This cycle provides a simple means of predicting eclipses.

Q.23 What should one look out for during a total solar eclipse?

Ans. The total phase of the eclipse would be accompanied by the onset of a rapidly darkening sky with an appearance which resembles evening twilight about 30 or 40 minutes after sunset. Here are things to look for on this occasion :

Contact Points: These are the points where the Sun and the moon seem to meet and leave as seen from the earth. A total solar eclipse shows four distinct contact points:

First Contact : The beginning of the eclipse itself, when the moon's disc just begins to obscure the Sun's disc as visible from the earth. This is the partial phase.

Second Contact : This takes place more than an hour after the first contact. This is the point when the Sun becomes fully eclipsed and totality begins

Third Contact : This is just when the totality is over

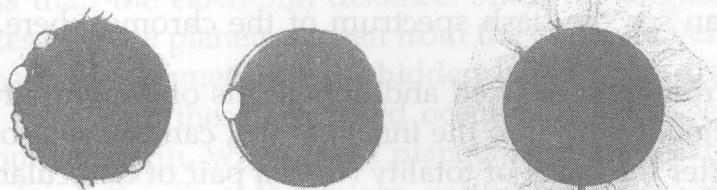


Fig. 14

and the Sun begins to emerge from behind the passing disc of the moon.

Fourth Contact : This is when the moon's disc leaves the Sun fully exposed again, in about 4 hours time.

Shadow Bands : These are wavy dark and light lines seen across terrestrial features about a minute before totality. They can be better seen on a smooth white surface and are caused due to irregularities in the refraction of the earth's atmosphere.

Bailey's Beads: Caused due to the shining of the Sun's rays through the valleys of the lunar limb just prior to totality. These visible parts of the Sun peeping through the moon's edges line up along the advancing disc of the moon and appear like a beaded necklace.

Diamond Ring : Becomes visible when only a speck of the Sun remains just before totality — with the speck of the Sun as the diamond and the inner corona as the ring.

Flash Spectrum : Just after the ring disappears, one can see the flash spectrum of the chromosphere.

Prominences : Red and orange jets of flaming fires, shooting up into the inner corona, can be seen soon after the onset of totality (with a pair of binoculars). These fires are gaseous material ejected from the Sun, millions of kms. above its surface. These can be seen only during totality.

Corona: The Sun's outer atmosphere visible only during totality. It is a pearly white glow enveloping the Sun and is about half a million times fainter than the Sun. This can be seen safely with naked eyes.

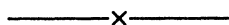
Stars and planets: It would be impossible to miss Venus at the time of totality. This very bright planet would be located 17 degrees east of the Sun. Look for the planet during the partial phases by covering Sun with your extended hand. Mercury would be 18 degrees west of the Sun and can be easily spotted provided the sky is clear.

The totality ends quite abruptly and features of the partial eclipse recur in the reverse order. Finally, the Sun emerges in its full glory and things are back to 'normal' as if nothing dramatic had happened.

Q. 24 Can there be eclipses involving the planets Mercury and Venus?

Ans. Mercury and Venus are planets which revolve around the Sun inside the orbit of the earth; i.e, the

average distance of these planets from the Sun is less than the earth-Sun distance. Since the angular sizes of these planets as seen from the earth are very small, they sometimes get hidden behind the disk of the moon; these are called occultations. As seen from the earth, when these planets pass across the disk of the Sun these are called Transits. By definition, both the occultations and the transits fall in the category of eclipses. These are taken note of but are not as spectacular, visually, or even in terms of the scientific studies or experiments that could be done during such occurrences.



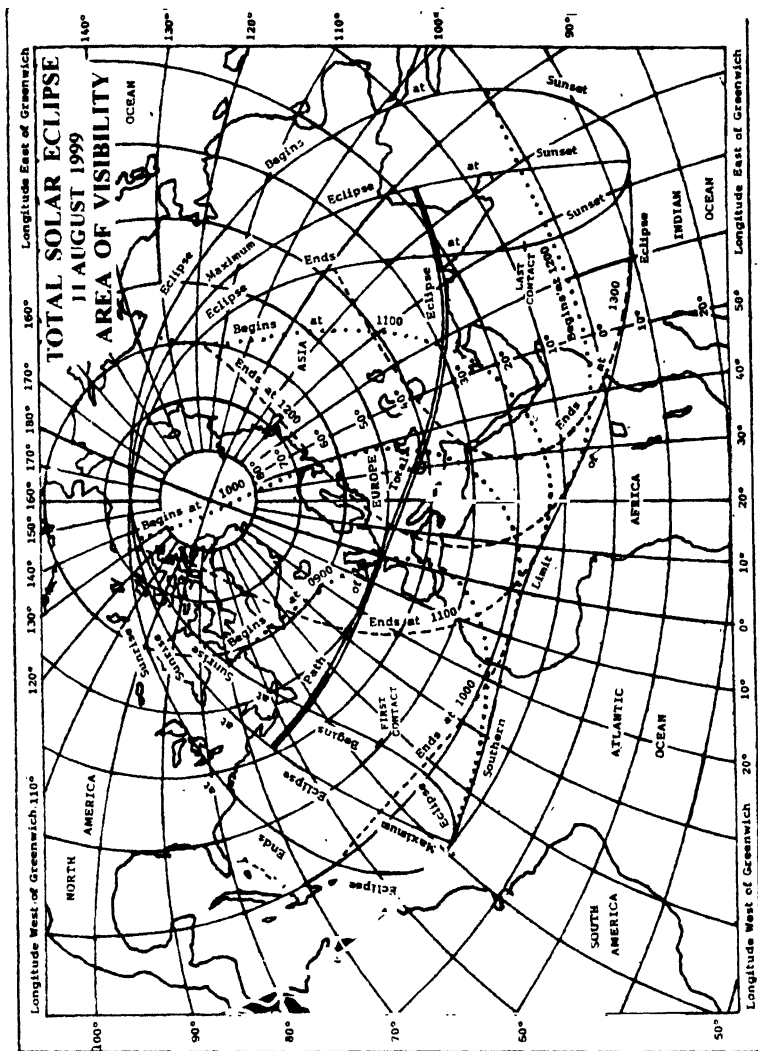
DOs AND DON'Ts FOR OBSERVING A SOLAR ECLIPSE

DOs

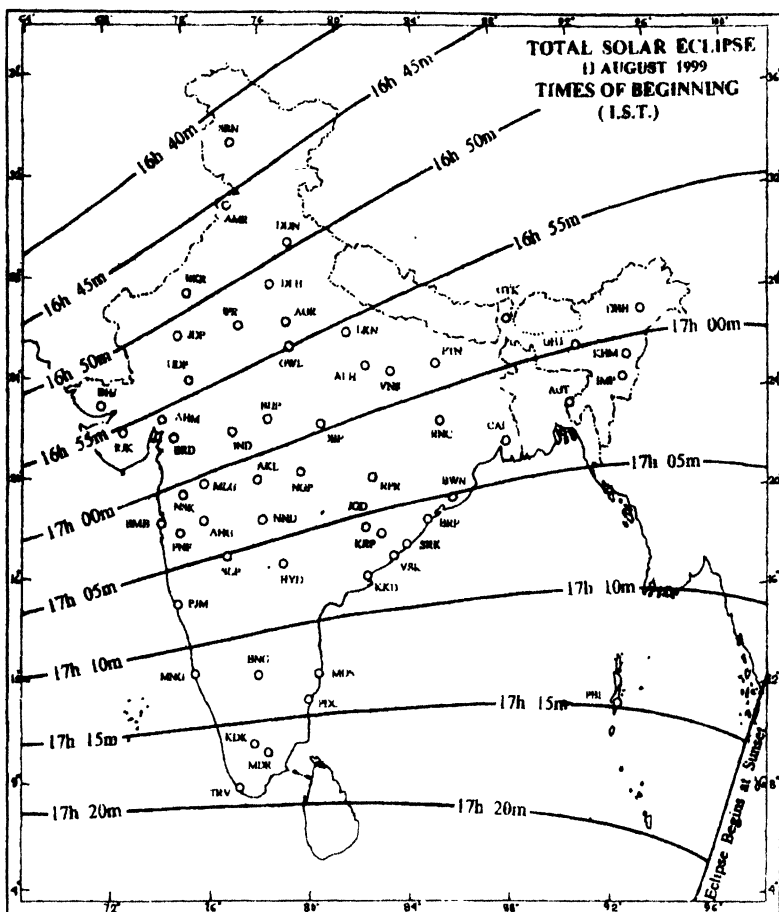
- Before onset of totality, it is best to view only a reflected image or projection of the Sun.
- Project the image of the Sun on a shaded wall through a pin hole. (This is provided in the Vigyan Prasara kit.)
- A small mirror covered with a piece of paper having a circular hole of diameter (1-2 cm) (also provided in the kit) can be used to project the image of the Sun on a shaded wall.
- A small telescope or binoculars can be used to project the image of the Sun on a white card/screen/wall. If binoculars or telescope has any plastic parts, take necessary precautions to protect them from heating and melting by sunlight.
- Direct viewing of the partially eclipsed Sun should be done only using a scientifically tested filter certified to be safe. A dark welder's glass (No.14) is ideal. The filter provided in the Vigyan Prasara kit can also be used. Use only one of your eyes for viewing the TSE. **In all cases, please examine the filter before use. A filter with pin holes/scratches must not be used. Don't touch, fold or wipe the film with your fingers, under any circumstances. Any scratch or fold on the film would render it unsafe for viewing the eclipsed Sun.**
- During totality of eclipse, look at the Sun only intermittently.
- Preferably, an experienced person should accompany eclipse watchers to announce the beginning and the end of totality.

DON'Ts

- Don't attempt to observe the partial or annular phase of any solar eclipse with naked eyes.
- Never look at the Sun through a telescope or binoculars. (In fact, you don't need these instruments to watch a solar eclipse.)
- Don't use any filter that simply reduces the visible intensity of the Sun. Fifty-two percent of the Sun's rays are in the infrared region of the spectrum. Damage to the eye is predominantly caused by this invisible infrared energy.
- Don't use smoked glass, colour film, sunglasses, non silvered black & white film, photographic neutral density filters and polarising filters. They are not safe.
- Don't use solar filters designed to thread into eye pieces and often sold with inexpensive telescopes.
- Don't look at a reflection of the Sun from coloured water.
- Don't look at the totally eclipsed Sun continuously; do it for a few seconds, intermittently.



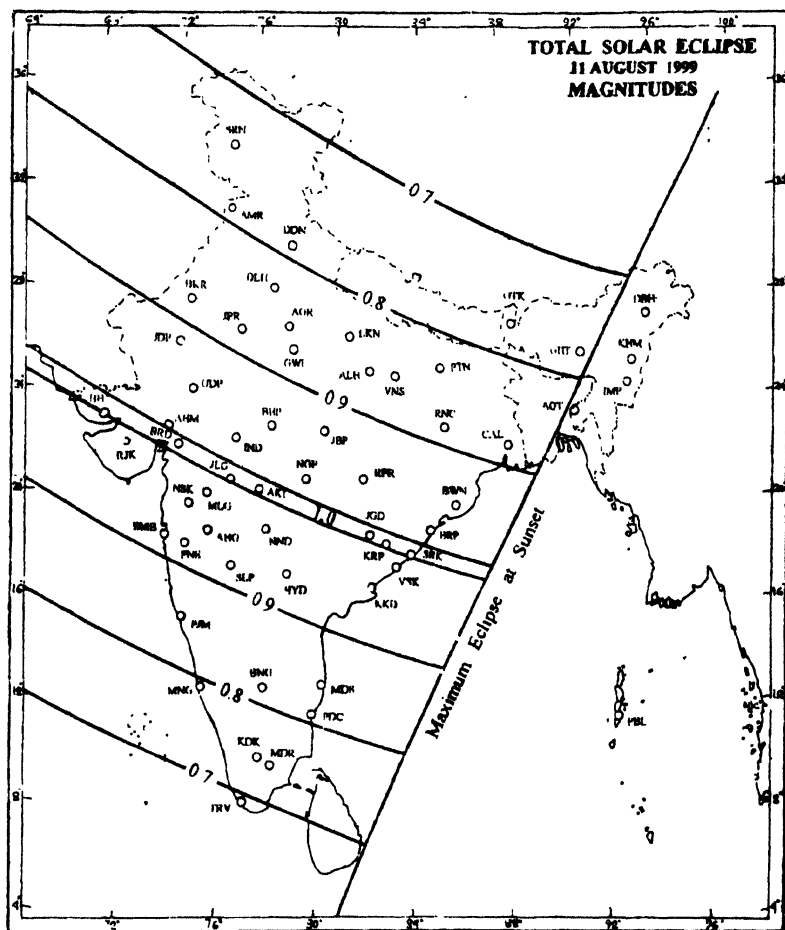
Source: Total Solar Eclipse of August 11, 1999, India Meteorological Department, New Delhi



The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate baseline

Based upon Survey of India Map with the permission of Surveyor General of India

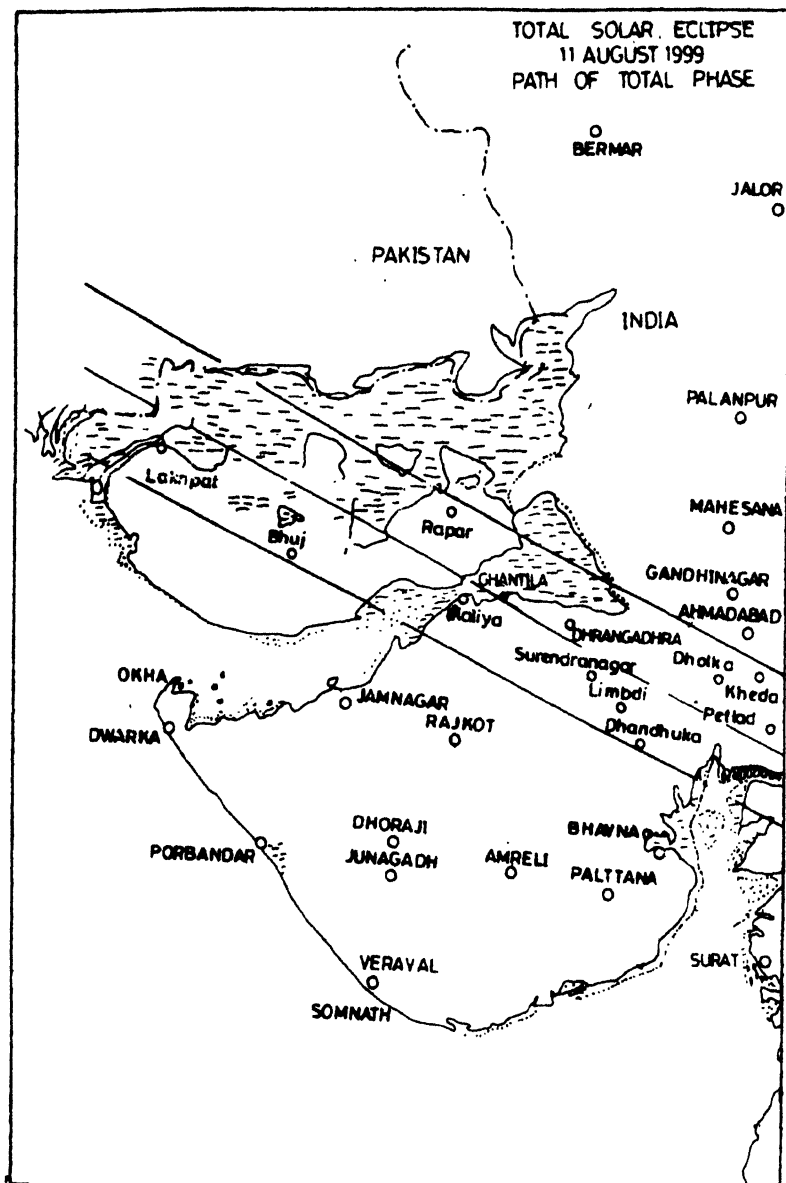
Source: Total Solar Eclipse of August 11, 1999; India Meteorological Department, New Delhi



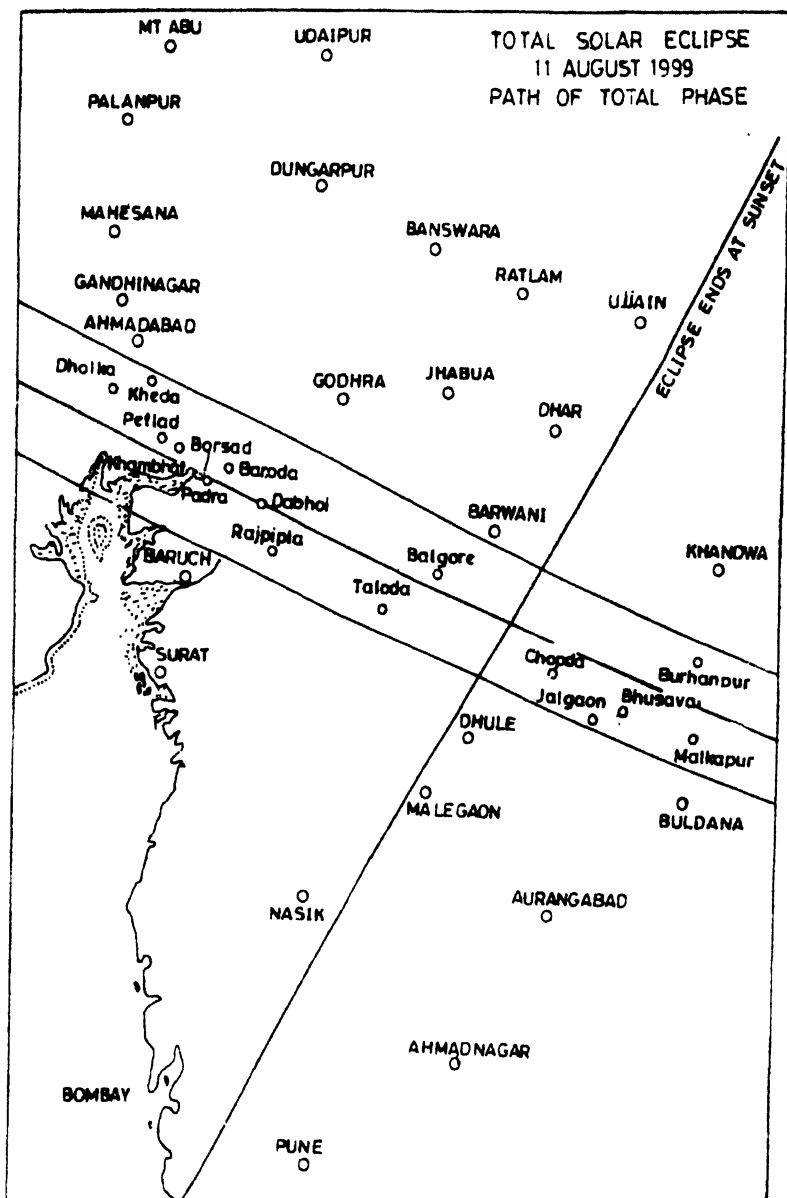
The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate baseline.

Based upon Survey of India Map with the permission of Surveyor General of India

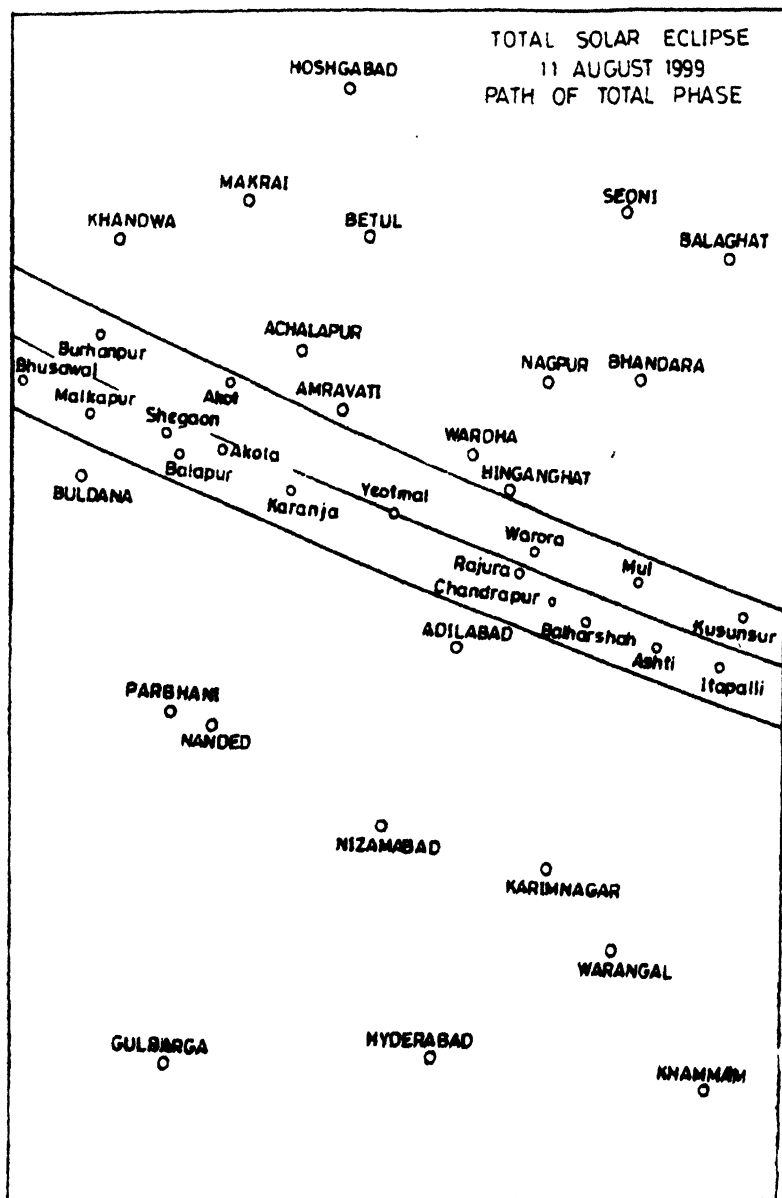
Source: Total Solar Eclipse of August 11, 1999; India Meteorological Department, New Delhi



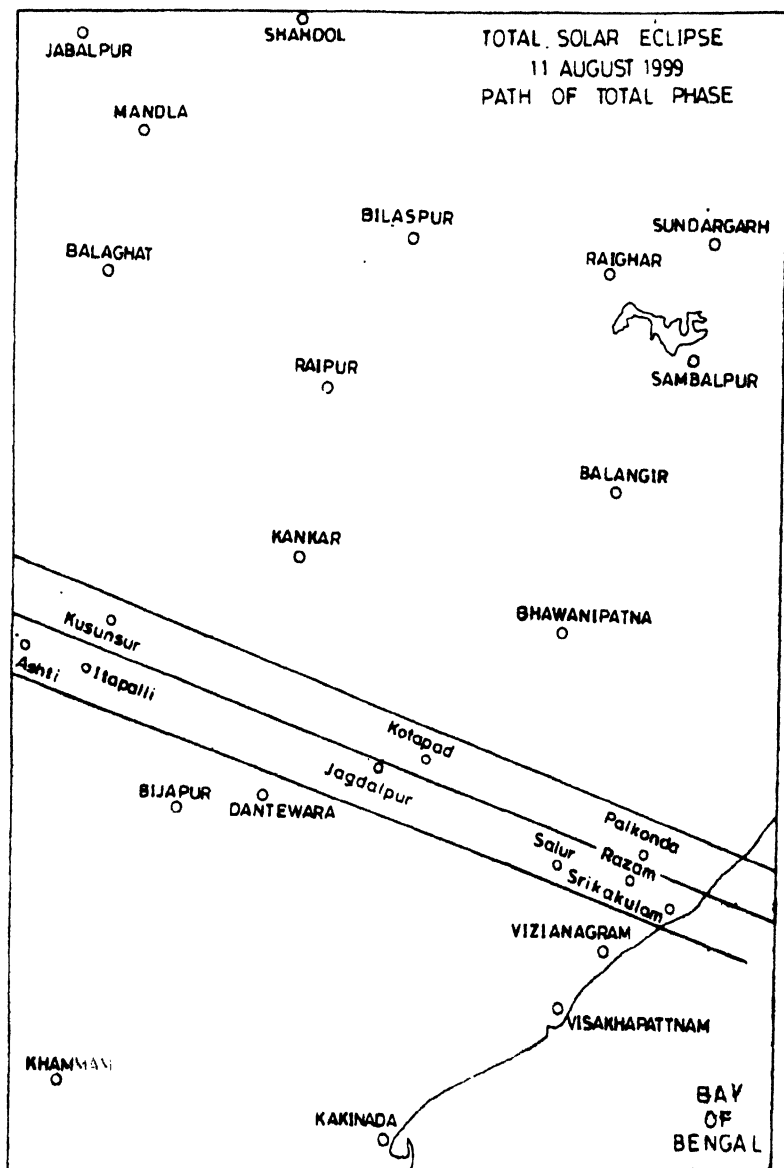
Source: Total Solar Eclipse of August 11, 1999; India Meteorological Department, New Delhi



Source: Total Solar Eclipse of August 11, 1999; India Meteorological Department, New Delhi



Source: Total Solar Eclipse of August 11, 1999; India Meteorological Department, New Delhi



Source: Total Solar Eclipse of August 11, 1999; India Meteorological Department, New Delhi

PATH OF CENTRAL PHASE (INDIA & NEIGHBOURHOOD)

Longitude	Latitude of			Indian Standard Time at						On Central Line						
	Northern Limit	Central Line	Southern Limit	Northern Limit		Central Line		Southern Limit		Maximum Duration	Sun's Alt.Az.					
				h	m	s	h	m	s			h	m	s		
+50 00	+33 51.3	+33 16.3	+32 41.6	17	29	38.5	17	30	39.7	17	31	40.1	1	54.5	42	260
51 00	33 19.0	32 44.3	32 10.0	17	31	38.9	17	32	39.3	17	33	38.7	1	52.3	41	262
52 00	32 46.7	32 12.4	31 38.4	17	33	36.4	17	34	35.8	17	35	34.2	1	50.1	40	263
53 00	32 14.5	31 40.6	31 07.0	17	35	30.8	17	36	29.1	17	37	26.5	1	47.9	39	264
54 00	31 42.4	31 09.0	30 35.8	17	37	22.0	17	38	19.2	17	39	15.4	1	45.7	38	266
+55 00	+31 10.6	+30 37.6	+30 04.9	17	39	09.8	17	40	05.8	17	41	00.7	1	43.5	37	267
56 00	30 39.0	30 06.4	29 34.2	17	40	54.2	17	41	48.9	17	42	42.5	1	41.3	35	268
57 00	30 07.6	29 35.5	29 03.8	17	42	35.0	17	43	28.3	17	44	20.6	1	39.0	34	269
58 00	29 36.5	29 04.9	28 33.7	17	44	12.2	17	45	04.1	17	45	55.0	1	36.8	33	270
59 00	29 05.8	28 34.7	28 03.9	17	45	45.7	17	46	36.2	17	47	25.6	1	34.6	32	271
+60 00	+28 35.4	+28 04.8	+27 34.6	17	47	15.5	17	48	04.5	17	48	52.4	1	32.4	31	272
61 00	28 05.4	27 35.4	27 05.7	17	48	41.4	17	49	28.9	17	50	15.4	1	30.3	29	273
62 00	27 35.8	27 06.3	26 37.1	17	50	03.6	17	50	49.6	17	51	34.6	1	28.1	28	274
63 00	27 06.6	26 37.7	26 09.1	17	51	22.0	17	52	06.5	17	52	50.0	1	26.0	27	274
64 00	26 37.9	26 09.5	25 41.4	17	52	36.5	17	53	19.6	17	54	01.6	1	23.9	26	275

Source: Total Solar Eclipse of August 11, 1999, India Meteorological Department, New Delhi

PATH OF CENTRAL PHASE (INDIA & NEIGHBOURHOOD) (Contd.)

Latitude		Indian Standard Time at										On Central Line	
Longitude	Northern Limit	Central Line	Southern Limit	Northern Limit		Central Line		Southern Limit		Maximum Duration		Sun's Alt.-Az.	
°	'	°	'	°	'	°	'	°	'	m	s	°	'
+65 00	+26 09.7	-25 41.8	+25 14.3	17 53	47.3	17 54	28.9	17 55	09.5	1	21.8	24	276
66 00	25 41.9	25 14.6	24 47.6	17 54	54.3	17 55	34.4	17 56	13.6	1	19.8	23	277
67 00	25 14.6	24 47.9	24 21.4	17 55	57.7	17 56	36.3	17 57	14.1	1	17.8	22	277
68 00	24 47.8	24 21.6	23 55.7	17 56	57.3	17 57	34.5	17 58	10.9	1	15.8	21	278
69 00	24 21.5	23 55.9	23 30.5	17 57	53.3	17 58	29.2	17 59	04.2	1	13.9	20	278
+70 00	+23 55.8	23 30.7	+23 05.9	17 58	45.8	17 59	20.3	17 59	54.0	1	12.0	19	279
71 00	23 30.5	23 05.9	22 41.7	18 59	34.8	18 00	07.9	18 00	40.3	1	10.2	17	280
72 00	23 05.7	22 41.7	22 18.0	18 00	20.3	18 01	52.2	18 01	23.3	1	08.3	16	280
73 00	22 41.5	22 18.0	21 54.8	18 01	02.4	18 02	33.1	18 02	02.9	1	06.6	15	281
74 00	22 17.8	21 54.8	21 32.1	18 01	41.3	18 02	10.7	18 02	39.4	1	04.8	14	281
+75 00	+21 54.6	+21 32.1	+21 10.0	18 02	16.9	18 02	45.1	18 03	12.7	1	03.1	13	282
76 00	21 31.9	21 10.0	20 48.3	18 02	49.4	18 03	16.5	18 03	42.9	1	01.4	12	282
77 00	21 09.7	20 48.3	20 27.1	18 03	18.8	18 03	44.7	18 04	10.1	0	59.8	11	282
78 00	20 48.0	20 27.1	20 06.4	18 03	45.1	18 04	10.1	18 04	34.4	0	58.2	10	283
79 00	20 26.8	20 06.4	19 46.2	18 04	08.6	18 04	32.5	18 04	55.8	0	56.6	9	283
+80 00	+20 06.2	+19 46.2	+19 26.4	18 04	29.1	18 04	52.1	18 05	14.7	0	55.1	7	284
81 00	19 45.9	19 26.7	19 07.3	18 04	47.3	18 05	07.7	18 05	30.2	0	53.6	6	284
82 00	+19 26.4	+19 07.5	+18 48.9	18 05	01.5	18 05	21.8	18 05	41.3	0	52.1	5	284

Source: Total Solar Eclipse of August 11, 1999; India Meteorological Department, New Delhi

LOCAL CIRCUMSTANCES OF THE PARTIAL PHASE

Station	Latitude	Longitude	Ht. above MSL	Partial Eclipse begins (IST)	P	V	Greatest Phase (IST)	Magnitude (%)	Partial Eclipse ends (IST)	P	V	
1	2	3	4	5	6	7	8	9	10	11	12	13
Achalpur	21 18	77 33	...	h m	s	°	h m	s	99.306	h m	s	°
Adilabad	19 37	78 30	...	17 3	34	291	18 5	8	99.321	...	...	...
Agartala	23 49	91 17	16	17 2	17	278	210	...	...	...	...	...
Agra	27 11	78 2	160	16 53	29	281	214	17 55	36.854	18 51	49	117
Ahmedabad	23 2	72 36	49	16 55	29	290	218	18 0	32.996	18 58	48	110
Ahmednagar	19 5	74 48	...	17 2	32	294	218	18 5	94.8	...	...	...
Aizawl	23 44	92 43	1097	17 2	33	278	209	...	...	...	...	...
Ajmer	26 27	74 38	486	16 52	10	284	216	17 56	15.899	18 53	55	115
Allahabad	25 28	81 52	96	16 57	41	281	213	17 57	53.861	...	...	...
Amaravati	20 56	77 48	...	17 1	30	290	216	18 3	36.999	...	...	...
Amreli	21 36	71 15	...	16 56	37	293	219	18 2	10.976	19 0	44	107
Amritsar	31 38	74 53	231	16 45	27	278	215	17 48	48.787	18 46	7	121
Aurangabad	19 53	75 23	...	17 1	42	293	218	18 4	97.2	...	...	...
Balasore	21 31	86 56	20	17 3	58	284	212	18 1	52.913	...	...	...
Bangalore	12 58	77 36	921	17 12	25	301	220	18 12	16.816	...	...	...

Source: Total Solar Eclipse of August 11, 1999, India Meteorological Department, New Delhi

LOCAL CIRCUMSTANCES OF THE PARTIAL PHASE (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13								
	°	'	°	'	mtr.	h	m	s	°	h	m	s	°							
Banswara	23	30	74	24	...	16	56	3	288	217	18	0	11	968	96.471	18	57	46	111	45
Barwani	22	3	74	57	...	16	58	25	290	217	18	2	6	997	99.829	18	59	19	109	42
Berhampur	19	18	84	51	...	17	6	2	288	214	18	4	43	982	98.043	...	...	...	...	...
Betul	21	30	77	30	...	17	0	35	289	216	18	2	55	988	98.815	...	...	...	...	...
Bharuch	21	41	73	1	...	16	57	43	292	218	18	2	21	995	99.599	19	0	15	108	40
Bhavnagar	21	46	72	11	...	16	57	2	292	219	18	2	7	989	98.991	19	0	21	108	40
Bhawanipatna	19	58	83	12	...	17	4	49	288	214	18	4	17	978	97.598	...	...	...	...	...
Bhopal	23	16	77	25	506	16	58	13	287	216	18	0	43	947	93.754	...	...	...	...	...
Bhubaneshwar	20	15	85	50	46	17	5	10	286	213	18	3	29	951	94.248	...	...	...	...	...
Bikaner	28	1	73	19	224	16	49	1	283	217	17	53	47	877	84.912	18	52	3	116	54
Buldana	20	32	76	14	...	17	1	15	291	217	18	4	3	995	99.670	...	...	...	...	...
Burdwan	23	16	87	54	32	17	2	15	281	211	17	59	41	866	83.378	...	...	...	...	...
Calcutta	22	32	88	20	6	17	3	8	282	211	18	0	24	880	85.139	...	...	...	...	...
Chandigarh	30	44	76	53	347	16	48	10	277	214	17	50	28	788	73.689	18	46	57	121	62
Chennai	13	4	80	15	7	17	12	53	300	219	18	11	49	840	80.109	...	...	...	...	...
Cuttack	20	29	85	52	26	17	4	54	286	213	18	3	14	946	93.509	...	...	...	...	...
Diamond Harbour	22	11	88	14	7	17	3	30	282	211	18	0	49	889	86.265	...	...	...	...	...
Dantewara	18	54	81	28	...	17	5	36	290	215	18	5	42	998	99.903	...	...	...	...	...
Darjeeling	27	3	88	16	2128	16	58	18	276	210	17	55	8	779	72.397	...	...	...	...	...
Dehradun	30	19	78	3	682	16	49	32	277	214	17	51	14	787	73.534	18	47	13	121	62

Source: Total Solar Eclipse of August 11, 1999; India Meteorological Department, New Delhi

LOCAL CIRCUMSTANCES OF THE PARTIAL PHASE (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13								
	°	'	°	'	mtr.	h	m	s	°	h	m	s	°	'	°					
Delhi	28	39	77	13	220	16	51	4	280	214	17	53	30	829	78.817	18	50	0	119	58
Dhanbad	23	47	86	26	258	17	1	19	281	212	17	59	23	864	83.191					--
Dhar	22	35	75	20	...	16	57	55	289	217	18	1	28	981	98.055	18	58	35	110	43
Dhoraji	21	45	70	37	...	16	55	56	293	220	18	1	50	974	97.187	19	0	41	107	39
Dhule	20	58	74	47	...	16	59	50	292	218	18	3	27	993	99.455	19	0	33	108	40
Dibrugarh	27	29	94	55	106	16	59	7	272	208										--
Dwarka	22	22	69	5	11	16	53	47	294	220	18	0	39	974	97.189	19	0	14	107	39
Gangtok	27	20	88	37	1768	16	58	5	275	210	17	54	43	770	71.347					--
Gaya	24	48	85	1	111	16	59	43	280	212	17	58	24	852	81.592					--
Guntur	16	18	80	29	...	17	8	38	295	217	18	8	36	926	90.971					--
Guwahati	26	10	91	45	55	16	59	58	275	209	17	55	22	775	71.975					--
Gwalior	26	14	78	15	207	16	54	50	282	214	17	56	54	873	84.339	18	53	2	116	53
Hardwar	29	56	78	8	274	16	50	4	278	214	17	51	47	794	74.445	18	47	46	121	61
Hazaribag	23	59	85	16	611	17	0	45	281	212	17	59	21	868	83.682					--
Hinganghat	20	34	78	53	...	17	2	29	290	216	18	4	1	998	99.903					--
Hoshangabad	22	46	77	45	...	16	59	3	287	215	18	1	21	956	94.868					--
Hyderabad	17	26	78	27	554	17	6	29	294	217	18	7	35	938	92.560					--
Imphal	24	48	93	57	801	17	1	37	276	209										--
Indore	22	44	75	50	...	16	58	1	289	216	18	1	18	973	97.074	18	58	16	111	44
Itanagar	27	8	93	40	...	16	59	18	273	208	17	53	41	743	67.897					--

Source: Total Solar Eclipse of August 11, 1999; India Meteorological Department, New Delhi

LOCAL CIRCUMSTANCES OF THE PARTIAL PHASE (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13								
	°	'	°	'	mtr.	h	m	s	°	h	m	s	°							
Jabalpur	23	9	79	57	393	16	59	39	285	214	18	0	52	928	91.382	18	52	55	116	53
Jaipur	26	55	75	49	436	16	52	22	283	215	17	55	46	879	85.092	18	52	55	116	53
Jaipur	20	48	83	54	...	17	4	1	286	214	18	3	15	953	94.412	18	52	55	116	53
Jamnagar	22	27	70	7	...	16	54	29	293	220	18	0	48	986	98.631	18	59	59	108	40
Jabal Rangapur	17	6	78	44	695	17	7	2	295	217	18	7	56	932	91.781	18	59	59	108	40
Jhabua	22	45	74	38	...	16	57	15	289	217	18	1	11	984	98.351	18	58	36	110	43
Jodhpur	26	18	73	2	224	16	51	10	286	217	17	56	10	917	90.032	18	54	32	114	50
Junagadh	21	31	70	36	...	16	56	16	294	220	18	2	8	968	96.473	19	0	57	107	38
Kakinada	16	57	82	15	...	17	8	16	293	216	18	7	40	956	94.786	18	58	36	110	43
Kalahandi	19	40	83	0	...	17	5	7	288	214	18	4	39	987	98.671	18	58	36	110	43
Kanker	20	15	81	32	...	17	3	56	288	215	18	4	11	984	98.368	18	58	36	110	43
Kanpur	26	29	80	21	126	16	55	42	281	213	17	56	37	850	81.441	18	58	36	110	43
Karimnagar	18	28	79	6	...	17	5	20	292	216	18	6	24	969	96.480	18	58	36	110	43
Kathmandu	27	42	85	12	1324	16	56	31	276	211	17	54	46	786	73.388	18	58	36	110	43
Kavalpur	12	35	78	50	725	17	13	16	301	219	18	12	30	816	77.054	18	58	36	110	43
Khamman	17	15	80	11	...	17	7	18	293	216	18	7	38	974	93.728	18	58	36	110	43
Khandwa	21	50	76	23	...	16	59	33	289	216	18	2	28	990	99.033	18	58	36	110	43
Kodaikanal	10	14	77	28	2343	17	16	24	306	221	18	14	50	742	67.843	18	58	36	110	43
Kohima	25	41	94	7	1405	17	0	47	275	208	18	9	20	894	86.979	18	58	36	110	43
Kurnool	15	50	78	3	281	17	8	31	297	218	18	9	20	894	86.979	18	58	36	110	43

Source: Total Solar Eclipse of August 11, 1999; India Meteorological Department, New Delhi

LOCAL CIRCUMSTANCES OF THE PARTIAL PHASE (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13								
	°	°	'	mtr.	h	m	s	°	°	h	m	s	°							
Lucknow	26	51	80	56	113	16	55	33	280	213	17	56	7	.838	79.834	---	---	---		
Machilipatnam	16	9	81	12	...	17	9	2	294	217	18	8	39	.927	91.192	---	---	---		
Madurai	9	55	78	7	133	17	16	57	306	221	18	15	0	.739	67.415	---	---	44		
Maheana	23	42	72	37	...	16	54	32	289	218	17	59	39	.980	97.948	18	57	59	111	
Mareshwar	22	11	75	37	...	16	58	38	289	217	18	1	59	.988	98.869	18	58	58	110	43
Makrai	22	4	77	8	...	16	59	39	289	216	18	2	13	.977	97.586	---	---	---	---	
Malda	25	5	88	9	...	17	0	21	278	210	17	57	31	.823	77.966	---	---	---	---	
Malegaon	20	30	74	40	...	17	0	26	292	218	18	4	0	.981	98.029	19	1	5	107	38
Malikangiri	18	22	81	56	...	17	6	25	291	215	18	6	13	.989	98.896	---	---	---	---	
Mangalore	12	52	74	50	22	17	11	43	303	221	18	12	30	.789	73.775	---	---	---	---	
Midnapur	22	26	87	20	45	17	3	2	282	212	18	0	45	.889	86.324	---	---	---	---	
Mount Abu	24	36	72	43	1220	16	53	20	288	218	17	58	28	.958	95.235	18	56	51	112	46
Mumbai	18	58	72	50	4	17	1	36	296	219	18	5	42	.927	91.243	19	3	5	104	34
Mursidabad	24	12	88	18	...	17	1	20	279	211	17	58	31	.842	80.338	---	---	---	---	
Mysore	12	18	76	39	767	17	13	8	303	220	18	12	59	.790	73.873	---	---	---	---	
Nagpur	21	9	79	5	312	17	1	49	289	215	18	3	19	.983	98.188	---	---	---	---	
Nanded	19	9	77	27	...	17	3	44	292	217	18	5	42	.972	96.901	---	---	---	---	
Nasik	20	2	73	50	...	17	0	37	294	218	18	4	30	.962	95.703	19	1	47	106	37
Nizamabad	18	40	78	10	...	17	4	42	293	217	18	6	14	.966	96.150	---	---	---	---	
Panaji	15	29	73	49	56	17	7	20	300	220	18	9	46	.848	81.222	---	---	---	---	

Source: Total Solar Eclipse of August 11, 1999, India Meteorological Department, New Delhi

LOCAL CIRCUMSTANCES OF THE PARTIAL PHASE (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13			
	°	'	°	mtr.	h	m	s	°	°	h	m	s	°	°	
Patna	25	36	85	8	53	16	58	51	279	211	17	57	24	.833	79.230
Pondicherry	11	56	79	50	6	17	14	22	302	219	18	12	57	.807	75.905
Port Blair	11	40	92	46	79	17	14	53	295	216	---	---	---	---	---
Porbandar	21	38	69	37	7	16	55	21	294	220	18	1	46	.962	95.648
Pune	18	31	73	53	559	17	2	52	296	219	18	6	20	.926	91.042
Puri	19	48	85	50	6	17	5	41	287	213	18	3	58	.962	95.620
Puruliya	23	20	86	25	255	17	1	49	282	212	17	59	55	.875	84.510
Raipur	21	14	81	39	298	17	2	45	287	214	18	3	3	.960	95.323
Rajamundry	17	0	81	46	...	17	8	5	293	216	18	7	41	.953	94.483
Rajkot	22	18	70	48	132	16	55	14	292	219	18	1	9	.989	98.972
Ranchi	23	23	85	23	652	17	1	28	282	212	18	0	3	.881	85.309
Rayagada	19	9	83	27	...	17	5	52	289	214	18	5	8	.996	99.688
Sambalpur	21	28	83	58	148	17	3	15	285	213	18	2	29	.936	92.338
Seoni	22	6	79	35	...	17	0	49	287	215	18	2	9	.956	94.876
Siliguri	26	44	88	26	127	16	58	39	276	210	17	55	28	.785	73.162
Shillong	25	35	91	53	1500	17	0	36	276	209	17	56	1	.787	73.434
Shimla	31	6	77	10	2202	16	47	56	277	214	17	50	0	.778	72.400
Sholapur	17	39	75	55	476	17	5	8	296	218	18	7	25	.922	90.555
Silchar	24	50	92	47	...	17	1	27	276	209	---	---	---	---	---
Srinagar	34	6	74	48	1586	16	42	11	275	215	17	45	1	.738	67.481

Source: Total Solar Eclipse of August 11, 1999, India Meteorological Department, New Delhi

LOCAL CIRCUMSTANCES OF THE PARTIAL PHASE (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13								
	°	'	°	'	mtr.	h	m	s	°	°	h	m	s	°	°					
Surat	21	12	72	52	...	16	58	19	293	218	18	2	57	.982	98.126	19	0	49	107	39
Thimpu	27	28	89	39	...	16	58	12	274	209	17	54	19	.761	70.172	---	---	---	---	---
Thumba	8	33	76	52	...	17	18	49	309	223	18	16	20	.691	61.554	---	---	---	---	---
Tirupati	13	40	79	20	...	17	11	52	299	219	18	11	23	.848	81.179	---	---	---	---	---
Trivandrum	8	31	77	0	61	17	18	54	309	223	18	16	21	.691	61.580	---	---	---	---	---
Udaipur (S.O.)	24	35	73	43	301	16	54	4	287	217	17	58	39	.950	94.126	18	56	37	112	47
Udaygiri	14	52	79	19	...	17	10	13	297	218	18	10	12	.880	85.121	---	---	---	---	---
Ujjain	23	11	75	46	496	16	57	22	288	216	18	0	44	.963	95.829	18	57	45	111	45
Varanasi	25	19	83	1	76	16	58	22	281	212	17	57	59	.855	82.041	---	---	---	---	---
Veraval	20	53	70	26	...	16	57	7	295	220	18	2	56	.951	94.355	19	1	39	106	37
Vishakapatnam	17	43	83	19	38	17	7	35	291	215	18	6	41	.983	98.195	---	---	---	---	---
Vizianagram	18	7	83	27	...	17	7	8	290	215	18	6	14	.994	99.478	---	---	---	---	---
Warangal	17	58	79	40	...	17	6	12	293	216	18	6	54	.961	95.485	---	---	---	---	---
Wardha	20	40	78	35	...	17	2	13	290	216	18	3	54	.998	99.913	---	---	---	---	---

"..." Data for height of stations above MSL are not available.

"—" Sunset occurs before eclipse ends.

Source: Total Solar Eclipse of August 11, 1999; India Meteorological Department, New Delhi

LOCAL CIRCUMSTANCES OF THE TOTAL PHASE

Station	Lat- tude	Long- tude	Ht. above MSL	Eclipse begins (IST)	P	V	Totality Begins (IST)	P	V	Greatest Alt. of Mag- Phase the ni- (IST) Sun tude (IST)	12	13	14	P	V	Eclipse Ends (IST)	P	V
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Ahiri	19 30	80 30	...	17 4 31	290 215	18 4 42	128 56	18 5 8	7 1 016	18 5 34	270 198	...	...	...	...	...	...	...
Akola	20 42	77 2	...	17 1 26	291 216	18 3 24	125 53	18 3 52	10 1 017	18 4 21	274 203	...	...	...	...	...	...	...
Anand	22 32	73 0	...	16 56	29 291 218	18 0 48	74 3 18	1 15 15	1 018 18 1 42	326 256	18 59	17 109	42	...	...	...	...	...
Balapur	20 42	76 53	...	17 1 21	291 217	18 3 25	135 64	18 3 52	11 1 017	18 4 19	264 192	...	...	...	...	...	...	...
Balharshah	19 55	79	...	17 3 32	290 216	18 4 17	120 48	18 4 45	8 1 016	18 5 12	279 207	...	...	...	...	...	...	...
Baroda	22 18	73 13	35	16 56	58 291 218	18 1 3	98 27	18 1 35	15 1 018	18 2 7	302 232	18 59	30 109	42	...	...	...	...
Bhuj	23 16	69 48	105	16 53	0 292 220	17 59	15 162	92 17 59	37 18 1 019	18 0 0	238 168	18 59	4 109	42	...	...	...	...
Bhusawal	21 2	75 47	...	17 0 19	291 217	18 3 1	145 74	18 3 26	12 1 017	18 3 51	254 182	...	...	...	...	...	...	...
Borsad	22 27	72 54	...	16 56	32 291 218	18 0 48	94 23	18 1 21	15 1 018	18 1 53	306 236	18 59	24 109	42	...	...	...	...
Burhanpur	21 17	76 16	...	17 0 14	290 217	18 2 44	74 3 18	3 9 11	1 017 18 3 33	326 255	...	...	...	...	...	...	...	...
Chandrapur	19 57	79 21	...	17 3 29	290 216	18 4 14	116 44	18 4 42	8 1 016	18 5 10	282 211	...	...	...	...	...	...	...
Dabhoi	22 11	73 25	...	16 57	16 291 218	18 1 13	103 33	18 1 46	15 1 018	18 2 18	296 226	18 59	35 109	41	...	...	...	...
Dhandhuka	22 21	72 2	...	16 56	4 292 219	18 1 1	167 96	18 1 20	16 1 019	18 1 38	233 162	18 59	43 109	41	...	...	...	...
Dholka	22 44	72 29	...	16 55	50 291 218	18 0 27	75 4 18	0 54	16 1 019	18 1 22	326 255	18 59	11 109	42	...	...	...	...
Dhrangadhra	22 59	71 28	...	16 54	45 291 219	17 59	52 100	29 18 0	25 17 1 018	18 0 57	301 230	18 59	7 109	42	...	...	...	...

Source: Total Solar Eclipse of August 11, 1999; India Meteorological Department, New Delhi

LOCAL CIRCUMSTANCES OF THE TOTAL PHASE (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19												
	°	'	''	h	m	s	°	°	°	h	m	s	°	°	°	h	m	s	°											
Ghantila	23	10	71	10	...	16	54	13	291	219	17	59	32	91	21	18	0	5	17	1,019	18	0	38	310	239	18	58	57	109	42
Jagdalpur	19	5	82	4	...	17	5	33	290	215	18	4	59	112	40	18	5	25	5	1,015	18	5	51	286	214	---	---	---	---	---
Jalgaon	21	5	75	40	...	17	0	11	291	217	18	2	56	144	73	18	3	22	12	1,017	18	3	47	255	184	---	---	---	---	---
Kalingapatnam	18	20	84	10	...	17	7	2	290	214	18	5	30	132	60	18	5	52	3	1,015	18	6	15	265	193	---	---	---	---	---
Karanja	20	29	77	32	...	17	1	58	291	216	18	3	41	132	60	18	4	8	10	1,017	18	4	35	267	196	---	---	---	---	---
Khambhat	22	19	72	38	...	16	56	32	291	218	18	0	57	129	58	18	1	29	15	1,018	18	2	0	271	200	18	59	37	109	41
Khangaon	20	42	76	37	...	17	1	13	291	217	18	3	30	152	81	18	3	52	11	1,017	18	4	14	247	175	---	---	---	---	---
Kheda	22	45	72	45	...	16	56	0	291	218	18	0	40	47	337	18	0	56	15	1,018	18	1	11	353	283	18	59	6	109	42
Koraput	18	49	82	43	913	17	6	5	290	215	18	5	13	122	51	18	5	37	4	1,015	18	6	2	275	203	---	---	---	---	---
Kotapad	19	4	82	24	...	17	5	41	290	215	18	4	58	96	24	18	5	23	5	1,015	18	5	48	302	230	---	---	---	---	---
Lakhpatt	23	49	68	48	...	16	51	19	292	220	17	58	3	139	69	17	58	35	20	1,020	17	59	8	262	192	18	58	32	109	42
Lakhtar	22	52	71	51	...	16	55	11	291	219	18	0	4	94	24	18	0	37	16	1,019	18	1	10	306	236	18	59	10	109	42
Limboi	22	34	71	53	...	16	55	39	291	219	18	0	30	136	66	18	1	1	16	1,019	18	1	32	264	193	18	59	30	109	41
Malia	23	9	71	22	...	16	54	24	291	219	17	59	38	81	11	18	0	9	17	1,019	18	0	39	320	250	18	58	55	109	42
Malkapur	20	53	76	17	...	17	0	48	291	217	18	3	12	140	68	18	3	38	11	1,017	18	4	4	259	188	---	---	---	---	---
Mul	20	4	79	43	...	17	3	29	290	216	18	4	11	72	1	18	4	33	8	1,016	18	4	55	326	255	---	---	---	---	---
Nadiad	22	41	72	55	...	16	56	12	291	218	18	0	47	47	337	18	1	3	15	1,018	18	1	18	353	283	18	59	8	109	42
Nandod	21	54	73	34	...	16	57	46	291	218	18	1	40	138	67	18	2	9	14	1,018	18	2	37	262	191	18	59	52	109	41
Padra	22	15	73	7	...	16	56	58	291	218	18	1	5	111	40	18	1	38	15	1,018	18	2	11	289	218	18	59	35	109	41
Palkonda	18	36	83	48	...	17	6	38	289	215	18	5	15	102	30	18	5	40	3	1,015	18	6	4	295	223	---	---	---	---	---

Source: Total Solar Eclipse of August 11, 1999; India Meteorological Department, New Delhi

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19											
Parvatipuram	18	47	83	28	...	17	6	19	289	215	18	5	8	86	14	18	5	32	4	1,015	18	5	55	311	240	...	...			
Parlakot	19	45	80	48	...	17	4	18	290	215	18	4	31	61	350	18	4	49	7	1,016	18	5	7	337	266	...	...			
Petlad	22	29	72	50	...	16	56	26	291	218	18	0	45	93	22	18	1	17	15	1,018	18	1	49	307	237	18	59	23	109	42
Rajpipla	21	55	73	26	...	16	57	39	291	218	18	1	39	144	73	18	2	6	14	1,018	18	2	34	256	185	18	59	53	109	41
Rajura	19	45	79	26	...	17	3	47	290	216	18	4	34	148	76	18	4	56	8	1,016	18	5	17	250	178	...	...	...	...	
Rapar	23	32	70	40	...	16	53	17	291	219	17	59	4	64	354	17	59	28	18	1,019	17	59	53	337	267	18	58	36	110	43
Razam	18	29	83	48	...	17	5	46	290	215	18	5	23	124	52	18	5	47	3	1,015	18	6	11	273	201	...	...	...	...	
Salur	18	31	83	15	...	17	6	35	290	215	18	5	23	154	82	18	5	51	4	1,015	18	6	9	243	171	...	...	...	...	
Shahpur (M.P.)	21	13	76	15	...	17	0	19	290	217	18	2	45	87	16	18	3	13	11	1,017	18	3	42	312	241	...	...	...	...	
Shegaon	20	48	76	46	...	17	1	10	291	217	18	3	16	124	53	18	3	45	11	1,017	18	4	14	275	204	...	...	...	...	
Srikakulam	18	17	83	57	...	17	7	3	290	215	18	5	43	160	88	18	5	58	3	1,015	18	6	13	236	164	...	...	...	...	
Surendranagar	22	43	71	43	...	16	55	18	291	219	18	0	14	124	53	18	0	47	16	1,019	18	1	21	277	206	18	59	22	109	42
Taloda	21	34	74	19	...	16	58	43	291	218	18	2	14	147	76	18	2	39	13	1,018	18	3	5	253	162	19	0	2	109	41
Warora	20	14	79	2	...	17	2	59	290	216	18	3	58	85	14	18	4	24	8	1,016	18	4	49	313	242	...	...	...	...	
Yeotmal	20	24	78	9	45	17	2	22	290	216	18	3	45	109	38	18	4	14	9	1,017	18	4	43	289	218	...	...	...	...	

" ----" Sunset occurs before eclipse ends.

47